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Bio-diesel—A global scenario

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ABSTRACT

Recent days, underground carbon resources are dwindling at a faster rate. This triggered primary interest in development of bio-fuel as substitute to Petroleum-based fuel for alleviating world energy and economic crisis. This review explores the environmental impacts of bio-fuels on the road transportation and a large-scale impact of bio-fuel crops on food-based agricultural lands, which are now more gainfully used for churning out vehicle fuel. A global bio-diesel production is depicted with an appropriate data from 1991 to 2012. Also this article explains in detail the bio-diesel status (which includes crop type, climatic conditions, yield, oil concentration, land use/availability, and policy impacts) of 27 different countries across the world. In addition, this article extends to classify the potential bio-fuel feedstocks obtainable in each country.

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1. Introduction

Nowadays, an interest in alternative fuel has become an important cornerstone to deal with, and it is likely to be driven by further research and development in upcoming decades. Due to global energy crisis, we find ourselves on the brink of depletion of underground carbon resources, economic crisis and environmental catastrophes.

The impact of using bio-fuels in road transportation is an important topic to debate with. The oil spill in Gulf of Mexico is an example of such environmental threats that fossil fuels pose [1]. The researchers from Swiss federal institute for materials science and technology have provided a complete picture of environmental benefits and costs of 26 different bio-fuels. The study revealed that most (21 out of 26) bio-fuels considerably reduced the green house emissions by 30 per cent when compared to fossil fuels. However, nearly half of them have exhibited greater environmental costs than gasoline. Also, the study disclosed that the fuels which showed over 50 per cent reduction in green house gases when compared with fossil fuels were bio-diesel made from several sources [2].

Bio-diesel is a common name given to an alternative fuel that is produced from edible or inedible vegetable oils and animal fats [3–6]. Recently, micro algae based bio-diesel is a newly emerging field, because high potential bio-diesel could be derived by micro algal biotechnology [7]. The higher heating values (HHVs) of bio-diesel are lower than that of gasoline (46 MJ/kg) and petro-diesel (43 MJ/kg), whereas HHVs of bio-diesel is higher than that of coal (32–37 MJ/kg). Although bio-diesel poses an advantage of environmental friendly fuel when compared to petro-diesel, its production cost is nearly double that of diesel [8]. The notion of using vegetable oil as an alternative fuel was first invented by the inventor of compression ignition (C.I.) engine, Rudolph Diesel, using peanut oil [9]. During Second World War, Brazil used Cotton seed oil as an emergency fuel. The country had prohibited the export of Cotton seed oil in order to substitute for imported diesel fuel [10]. After Second World War, the United States used corn oil and cotton seed oil, and their blends with neat diesel as a substitute to imported diesel [11]. The pressing need to go for alternative fuel was triggered after petrol crisis in 1973 and gulf war in 1991 [12]. Today, bio-diesel is produced in various countries worldwide and each country has allocated certain percent of land for cultivating crops for producing bio-diesel, as well each country pose their own bio-fuel policy. For example, the European union (EU) promotes bio-fuel policy by achieving 20 per cent of energy used in EU and almost 10 per cent of each member state's transport fuel must come from the renewable energy sources by 2020 [13].

Though there have been numerous case-studies on bio-diesel scenario, a very few is concerned with bio-diesel status of various countries. Based on the above actualities, one such attempt has been made to present the positive and negative impacts of bio-diesel on the crop production and land use. Also, this article extends to elaborate the bio-diesel scenario of various countries across the globe.

2. Impacts of bio-diesel

The political unsteadiness in the Organization of Petroleum Exporting Countries (OPEC) has paved way for higher prices of fossil fuels. Alternatively, the countries with small fuel production and those without fossil fuel production would gain from the utilization of existing land resources for the plantation of bio-fuel crops. The list of countries producing petroleum products (based on geographical regions) is depicted in Table 1. As a result, the production of bio-diesel increases year by year, and in near future, bio-diesel is likely to remain the main bio-fuel produced worldwide [14]. The world bio-diesel production from 1991 to 2012 is depicted in Table 2. One could perceive from Table 2 that the world bio-diesel production gradually increased since 1991, and it kept on increasing up to 2012. This picture shows the demand of bio-diesel in the world fuel market. Since the use of bio-diesel in road transportation vehicles have dominated the use of petro-diesel, now, it is time to critically analyze the positive and negative impacts of using bio-diesel in such transportation vehicles.

Rowe et al. [15] attempted to study the potential environmental impacts of bio-fuel crops in the United Kingdom (UK). The study was primarily focused on the second generation bio-energy crops, such as *Miscanthus* (a bulky variety of grass) and short rotation coppice (SRC), such as Willow and Poplar trees when compared with traditional first generation crops (wheat and oil rapeseed). The study revealed that the land availability in the UK to raise bio-fuel crops is not sufficient to meet UK's target for renewable energy production, and the water demand from many bio-fuel crops is very much higher than that of traditional crops. The review also projected the potential benefits of second generation crops, such as improvements in soil quality, carbon sequestered in

Table 1
List of countries producing petroleum products [1].

Geographic regions	*Oil producing countries*
Europe & Central Asia	Lithuania, Russia, Azerbaijan Turkey, Kazakhstan, and Turkmenistan
Latin America and Caribbean	Barbados, Belize, Cuba, Guatemala, Trinidad and Tobago, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador (OPEC Member), Guyana, Peru, Suriname, and Venezuela (OPEC Member)
Middle East and North Africa	Algeria (OPEC Member), Bahrain, Iran (OPEC Member), Iraq (OPEC Member), Kuwait (OPEC Member), Libya (OPEC Member), Oman Qatar (OPEC Member), Saudi Arabia (OPEC Member), Syria, United Arab Emirates (OPEC Member), and Yemen
SubSaharan countries	Angola (OPEC Member), Cameroon, Chad, Côte d′Ivoire, Democratic Republic of the Congo, Republic of the Congo, Egypt, Equatorial Guinea, Gabon Kenya, Nigeria (OPEC Member), South Africa, Sudan, and Tunisia.

Table 2
World bio-diesel production, 1991–2012.
Source: Compiled by Earth Policy Institute with 1991–1999 data from F.O. Licht data, cited in Suzanne Hunt and Peter Stair, "Biofuels Hit a Gusher," *Vital Signs 2006–2007* (Washington, DC: Worldwatch Institute, 2006), pp. 40–41; 2000–2004 data from F.O. Licht, *World Ethanol and Biofuels Report*, vol. 7, no. 2 (23 September 2008), p. 29; 2005–2012 data from F.O.Licht, *World Ethanol and Biofuels Report*, vol. 10, no. 14 (27 March 2012), p. 281.

Year	Production Million gallons
1991	3
1992	23
1993	38
1994	75
1995	108
1996	144
1997	151
1998	155
1999	190
2000	213
2001	265
2002	383
2003	510
2004	614
2005	995
2006	1,710
2007	2,775
2008	4,132
2009	4,699
2010	4,893
2011	5,651
2012*	5,670

* Projection.

the soil, and soil erosion. In addition, recent report portrays that the expansion of bio-fuels industry has contributed to rise in prices of foods and a shortage of land for food-based agriculture in the countries of Asia, Africa, and Latin America [16].

Mazzoleni et al. [17] conducted a real-world tail pipe emission for around 200 school buses using 20 per cent bio-diesel blend and noticed unexpected results with the exhaust emissions. The particulate emission increased by a factor of 1.8 and the similar trend was also evident from the carbon monoxide and hydrocarbon emissions. The study disclosed that the bio-diesel used in the tested buses did not meet the US standards. Overall, the study suggested a need to enforce more stringent quality testing methods in bio-fuel production in forthcoming days.

Overall, the key findings of several researchers have disclosed that the use of bio-diesel in transportation vehicles (real-world testing) would eventually escort to greater harmful impacts than gains.

3. Global bio-diesel status

The traditional/possible feedstocks for bio-diesel production, agro-climatic conditions to raise bio-fuel crops, land use/availability, and the policy impacts on sustainable bio-fuel development in both developing and developed countries are depicted in detail, also, the problems in implementing sustainable bio-fuel market in those countries are discussed deeply in the following sections.

3.1. Africa (an inclusive view on South Africa)

In Africa there is a large bio-energy resource base, but very few small scale bio-energy production plants are available in the country. Although the primary interest in development of renewable energy technologies has received public and legislative attention in several developing and developed nations, the development of such energy in Africa has received less attention [18]. The market feasibility of bio-diesel in South Africa was about 1 billion liters in 2007. The country would require producing 10% and even more of its requirements by 2010 and in upcoming years through the implementation of several bio-diesel production plants. The increase in bio-diesel production in South Africa will increase the net export of oil cake from being a net importer. However, without government subsidies and imposed legislation, the country′s commercial bio-diesel production does not seem to be financially feasible [19]. In rural Africa there is a great need to develop energy to build up the country and to alleviate its poverty. The use of *Jatropha* oil for bio-diesel production would add more profitable venture at a community level. The *Jatropha* plantation would require 8 ha after 5 years of growth to provide enough seeds to power a multifunctional platform (one way of delivering energy to rural Africa) for development of rural sub-Saharan Africa [20].

In South Africa, the seeds and grains grown for commercial use include barley, canola, dry beans, sorghum, ground nuts, maize, sunflower, soybeans, and sweet lupines. Among these the important oil seed crops are canola, ground nut, sunflower and soybean out of which, canola, sunflower and soybean are oil seed crops targeted for bio-diesel production in South Africa [21]. Mulugetta [22] evaluated the economics of bio-diesel production in Africa. The economic assessment was carried out in three different countries, such as Ghana, Tanzania, and Kenya using three different feedstocks, such as Palm oil, *Jatropha*, and Castor oil. The study revealed that the potential revenue of oil per liter showed that Palm oil performed slightly better than *Jatropha* and castor oils. Also, the by-product from Palm seeds could be used both as an animal feed as well as fertilizer, whereas the by-product from *Jatropha* and castor could only be used as fertilizer. Overall, the study disclosed that the performance of *Jatropha* is interesting due to resilient of the crop to grow under wide range of climatic and soil conditions.

The Eastern Cape province of South Africa is playing a host to a number of bio-diesel projects. The region consists of most of the under-utilized and communal land of South Africa. The country is at the initiating stage of commercial bio-fuel production to capture the global market. However, there were number of concerns that were against the development of alternative energy in the region, such as social and ecological risks, lack of understanding the new technology and environmental concerns [23]. Alternatively, bio-diesel production in Africa would contribute to job creation, energy security and reduction of green house gas emissions. There are no proper bio-fuel policy/targets except in few countries such as South Africa. However, small-localized bio-diesel plant would be a feasible option for development of bio-diesel industry in Africa [24].

3.2. Argentina

In Argentina, soybean and sunflower seeds provide an opportunity to produce a short-term alternative fuel to petroleum-based fuels used in road transport vehicles. The country′s main oil bearing crop is soybean, which accounts for 80% of the oil bearing plant production by volume. The vegetable oil industry of the country is one amongst the most developed industry in the world with a 160, 000 tones per day crushing capacity. In April 2006, "Senator Falco′s law" was introduced in the country, which provided a basis of mandatory blending of 5% of bio-fuels into diesel and gasoline, respectively. It was projected that the demand of bio-diesel would grow annually between 2010 and 2020. The bio-diesel demand was estimated to be 700 millions of liters in 2010 and it was projected to be around 987 millions of liters in

2020. To meet the above demand, the country has to invest US $ 200 million for the development of sustainable bio-diesel industry [25]. Falasca et al. [26] analyzed the suitability of *Crambe abyssinica* bio-fuel in Argentina. The study was primarily focused on identifying the suitable agro climatic area for the cultivation of *Crambe abyssinica* in the country. The seeds of *Crambe* contain 35.6–42.8% of oil. The south and south east of Buenos Aires province was identified to be the suitable zone for crop cultivation.

Wassner et al. [27] evaluated *Jatropha macrocarpa* as a bio-fuel crop for bio-diesel production in arid lands of the dry Chaco in Argentina. The seed production of the crop was noted to be low and variable, with a mean seed production of 87 g/plant and a maximum of 151 g/plant, respectively. And, the seed proportion of *Jatropha macrocarpa* was found to be lower than that of commonly used bio-diesel feedstock, *Jatropha curcas*. However, the oil concentration of the crop was found to be very similar to *Jatropha curcas*. Finally, the bio-diesel quality parameters of *Jatropha macrocarpa*, such as iodine value and cetane number indicated only slight differences with respect to the European standards.

3.3. Australia

The development of sustainable bio-diesel industry in Australia is on the move. The preliminary evaluation of exotic bio-fuel crop cultivation in the marginal regions of mainland Australia indicated that 20–30 million hectares are potentially suitable for crop production. The assessment of three exotic bio-fuel crops, such as Physic nut, Pongam and Indian mustard provides a good prospect for expansion of bio-fuel industry in the country [28]. Hathurusingha [29] analyzed the periodic variation in kernel oil content and fatty acid profiles of native Australian potential bio-diesel feedstock, *Calophyllum inophyllum*. The objective of the study was to identify the feasibility of the feedstock during two different fruiting periods (winter 2008 and autumn 2009). Cardwell, Townsville and Yeppoon are the three different northern Queensland provinces considered to examine the suitability of the feedstock. The mean annual rainfall, the maximum temperature and the number of dry months in the selected northern Queensland provenances had a greater impact on oil concentration in kernels. The observations showed that the winter seeds contained lower amount of oil when compared to autumn seeds. And, the fatty acid profile results exposed that the Cardwell seed oil recorded highest periodic variations. Overall, the study recommended that the winter seed oils could also be used in the production of bio-diesel, which complies with the ASTM standards.

3.4. Bangladesh

In Bangladesh, *Pongamia pinnata* cultivation project could be proposed to provide an employment opportunity and to trim down the import of diesel fuel. The country has 0.32 million hectare of waste land in which 0.67 million MT per year bio-diesel can be produced. This could help the country to cut-off its diesel import by around 28% (2.4 million MT diesel fuel) [30].

Morshed et al. [31] investigated the probable bio-diesel production from rubber seed oil in Bangladesh. In the country around 91.8 thousand hectare of land is used for rubber crop cultivation, where the extraction of rubber seed oil is around 217 kg-oil/ha. Therefore, the projected yearly rubber seed oil extraction in the country accounts for $\sim$0.02 million MT. Also, the properties of prepared bio-diesel from rubber seed oil were found to be comparable with petro-diesel.

3.5. Brazil

In Brazil, soybeans have been traditionally used as potential feedstock for bio-diesel production. Also, the country is the leading producer of ethanol from sugarcane sucrose. The region with largest bio-diesel production is the centre-west region of the country followed by southern province. Conversely the south-east region of the country has only nominal bio-diesel production capacity despite its largest urban centers and large number of bio-diesel consumers. At present, the country is searching for other alternative oilseed crops due to the increased consumption of bio-diesel and low oil productivity from soybean seeds [32].

César and Batalha [33] investigated the case of palm′s social projects in Brazil. The states of Para, Amapa and Amazonas were the regions noted with more favorable climatic conditions for palm cultivation. The excellent climatic condition of para offers more encouraging and commercial cultivation of palm, so the survey was mainly focused on the northern Brazilian state of Para. The survey reported that the use of palm in bio-diesel production is a viable mid-term option, which develops the representative inclusion of farmers in the northern region of Brazil.

Visser et al. [34] studied the bio-ethanol production from bio-diesel co-products in Brazil and found that all oil bearing crops have shown the potential to meet the ethanol demands for bio-diesel production. Although soybeans and cotton seeds had shown great ethanol production when compared to other oil crops, oil extraction co-products have the potential to produce large quantity of cellulose ethanol.

Takashi and Ortega [35] assessed the suitability of oleaginous crops, such as cotton seed, soybean, canola, sunflower, and palm crops in Brazil to produce bio-diesel. The study disclosed that the energy assessment of oleaginous crops cannot be considered sustainable to produce bio-diesel by conventional farming as prescribed by “The National Program for production and use of Bio-diesel”, commenced in December 2004 in Brazil. Finally, the study suggested the use of life cycle assessment methodology integrated with emergy methodology to critically analyze the sustainability of oleaginous crops in Brazil. Borzoni et al. [36] adopted a multi-scale integrated analysis of societal and ecosystem metabolism approach to evaluate the sustainability of soybean bio-diesel in Brazil. Based on the study, it was figured out that the use of soybean as a bio-diesel feedstock may seem to be feasible, but its desirability is questionable.

On the whole, studies claim that the Brazilian bio-diesel policy failed to justify the proposed targets and results. The policy does not seem to posses the objective of promoting social and environmental considerations of sustainability. So the Promised Land has not yet been reached [37–39].

3.6. Canada

In Canada, the oil seed crops with highest potential for bio-diesel production were noted with canola, sunflower and soybeans. The oilseed crops were dominated to grow in the eastern and western Canadian provinces. Around 24% of eastern Canadian farmlands and 23% of western Canadian farmlands were planted with oil seed crops. Hence the higher cold flow properties of bio-diesel would make the fuel more complicated to be used during Canadian winters. The bio-diesel feedstocks with the lowest possible cold flow properties are most recommended. Moreover, these properties for canola and soybeans were estimated to be lower than that of the sunflower. Conversely the soybeans are entirely grown in eastern province of Ontario, and the canola oil seed crops are solely grown in the western province. The reports based on the impacts of increased bio-diesel production on the green house gas emissions from the field crops grown in eastern

and western province of Canada has revealed that the emissions were found to be lesser in eastern Canada and higher in western Canada. Therefore, soybean might be a better feedstock for bio-diesel production in Canada than canola, due to the nitrogen fixing capability, and the ability to produce extra feed and bulk yields of soybeans in eastern Canada [40].

3.7. Chile

At present, Chile has a strong dependence on foreign sources for energy needs. Around 70% of net energy consumed by several sectors in Chile is imported. Also, the country does not have enough arable lands to raise potential bio-fuel crops, which would strongly compete with the lands used for food-based agriculture. Since the focal point on first-generation bio-fuels in Chile is not promising, the country has to look forward to produce bio-diesel from second-generation bio-fuel crops like residual wood from exotic species of Radiata pine and eucalyptus. Also, the new research and development projects have to be proposed on biomass conversion technologies in Chile [41]. In contrast, low-cost prospective feedstocks, such as camelina, which has wide adaptation to different climatic and soil conditions, could be cultivated in Chile. Berti et al. [42] studied the optimum seeding date to maximize the yield of camelina seeds in south central Chile. The examination reported that the seeding of camelina in south central region can be done before 15 may in Chillán, Los Angels and EI Carment, and before 30 may in Osorno province. Among different provinces, Osorno reported highest yield. The study also suggested a need to create a novel market of camelina cultivation in south central Chile.

Iriarte et al. [43] studied the evolution towards a more environmentally suitable rapeseed bio-diesel production in central-southern area of Chile. The use of rapeseed as a major feedstock for short-term bio-diesel production in Chile is under consideration. The analysis showed that the degraded grasslands in the central-southern regions could be considered for rapeseed plantation.

3.8. China

In China, rapeseed based bio-diesel has been considered an apt substitute for diesel fuel. Brassica Campestris, Brassica Juncea and Brassica Napus are the three major types of rapeseed crops cultivated in the country. Based on the inspection conducted in 2007, the country ranked top in rapeseed production. The popularity of bio-diesel in China is growing year by year and the projected usage of bio-diesel in the country in 2020 would account for 2 million tons. However, the estimation of total energy cost of rapeseed-based bio-diesel as a promising alternative energy in china had revealed that the overall energy cost showed a negative energy return, which stresses the changes to be brought out in the bio-diesel policy of the country [44]. To overcome the restriction of large-scale bio-diesel production in China, micro algae could be considered a prospective raw material for bio-diesel production. The cultivation of micro algae can be done in three different ways, such as autotrophic, heterotrophic and mixotrophic. Apart from this, the bio-fuel production from micro algae could fix carbon monoxide emissions in China, and the reduction of eutrophication in the aquatic environment is also possible [45].

3.9. Crete island

In Crete Island, a case study was conducted to set up a small-scale bio-diesel plant to stabilize the diesel demand in the Island. Based on the review conducted in 2005, around 148, 039 vehicles were diesel powered in Crete. It was estimated that the bio-diesel demand in Crete would move toward 10, 000 tons on annual basis. The abundant biomass available in the Island could be used as a feasible raw material for bio-diesel production. The small-scale bio-diesel production facility in Crete can be installed at low investment cost that can guarantee the turnover by running the plant 2/3 of its annual running capacity [46].

3.10. Cuba

Like Chile, Cuba is also reliant on foreign sources for its energy and transportation needs. The country is in imperative need to conduct research and developmental programs to uncover possible renewable technologies to partially replace the conventional energy sources to resolve its energy demands. Based on the study conducted, the possible feedstock for bio-diesel production in Cuba is *Jatropha curcas.* Piloto et al. [47] characterized the fatty acid ethyl ester (FAEE) composition of two different *Jatropha curcas* species planted in Cuba. The San josé and Guantanamo were two different plantation regions of Cuba considered for analysis. The exploration indicated that the higher acid and peroxide values were noted with Guantanamo based FAEE when compared to FAEE from San josé. This trend was primarily due to the higher cetane number of *Jatropha* based FAEE in Guantanamo.

Martin et al. [48] investigated the suitability of inedible oilseed crops, such as Jatropha, neem, moringa, trisperma, castor, and candlenut for vital exploitation of their fraction for bio-diesel production in Cuba. The investigation showed that the seeds with highest oil potential were trisperma seeds. Despite trisperma′s highest oil potential among other tested seeds, the presence of poly unsaturated free fatty acids formulate them to be unsuitable for bio-diesel production. On the other hand, *Jatropha curcas* was found to be the promising feedstock for bio-diesel production in Cuba based on their oil yield and fatty acid composition in the oil. The comparatively high protein content in tresperma and castor cakes proved them to be a potential candidate for fermentation process. In contrary, neem and moringa husks proved to be a probable raw material for ethanol production.

3.11. Greece

In Greece, the use of bio-diesel would play a key role in transportation sector. The projected bio-diesel objective of Greece was around 5.75% in the year 2010. And it is likely to grow annually in the near future. The oilseed crops obtainable for bio-diesel production in Greece are sunflower, soybean, cotton, tobacco, tomato, and rapeseed. Among these the primarily cultivated oil seed crops with promising options for bio-diesel production are sunflower and cotton seeds. The sunflower cultivation is principally witnessed in the northern regions of Macedonia and Thrace. Further, rapeseed cultivation in Greece is at the demonstration levels in several areas. On the other hand, tomato seeds and tobacco seeds have been identified as future imperative feedstocks for bio-diesel production, because of their higher bio-diesel potential [49].

Schinas et al. [50] identified pumpkin seed oil as an unconventional raw material for bio-diesel production in Greece. Although the pumpkin seed oil is not commercially offered in Greek markets, the seeds can be collected and crushed in the laboratory level. The central advantage of pumpkin seed oil over other vegetable crops in Greece is the rich oil content, with an average oil yield of 42–45%. Thus, pumpkin seed oils can be considered a vital source for economical bio-diesel production in Mediterranean areas of Greece.

3.12. India

India is the fourth largest petroleum consumer after United States, China, and Japan. The country relies heavily on imported crude oil for about 80% of its total requirements. In the country, *Jatropha curcas* was identified to be the most suitable oilseed crop for bio-diesel production. The planning commission of India had targeted to plant *Jatropha* in 11.2–13.4 million hectares of land by the end of 2011/2012. At the moment, commercial production of *Jatropha*-based bio-diesel is diminutive due to the unavailability of high yielding and drought-tolerant concerns of *Jatropha* seeds. However, these impediments in bio-diesel production have been forecasted to catch up the international market in approaching years by appropriately operating 20 large-capacity bio-diesel production plants accessible in the country [51]. Singh et al. [52] examined the growth and yield performance of *Jatropha curcas* in seven specific sites in India. The exploration reported that the significant variations were site-specific. In addition, an inclusive view on life cycle assessment of *Jatropha* bio-diesel production in India was estimated by Kumar et al. [53]. The estimated green house gas emissions, net energy ratio, total life cycle inventory and process energy were in good compliance with the previous literature values. It is also indispensable to weigh up the environmental impacts of *Jatropha curcas* before implementing it on large-scale in India. Though environmental impacts on reduction of green house gases had been evident by *Jatropha*, the impacts on acidification, ecotoxicity, eutrophication and water depletion all showed unenthusiastic environmental impacts. Furthermore, studies have to be conducted in examining the performance of *Jatropha curcas* in different regions of the country [54].

3.13. Iran

In the Islamic republic of Iran about 7% of land area is covered with forests, which affords ample sum of resources for bio-fuel production. The traditional fishing centers in Caspian Sea and Persian Gulf can promote the use of fish oil and other oilseed crops such as palm, *Jatropha*, castor, and algae as practical source for bio-diesel production. In contrast, the country consumes around 1.5 million tons of edible cooking oil, out of which about 20% is considered as waste, which could be considered a possible raw material for bio-diesel production to chop down the imports of petroleum derivatives in the country [55]. Safieddin et al. [56] investigated the bio-diesel production potential from edible oil seeds in Iran. The study disclosed that the cultivation of oilseed crops can be elusively done in the provinces distributed in north, north-east, east and central Iran with the land area of 1,068,831.2 ha. Among different oilseed crops, canola, soybean, cotton, almond, corn, and walnut can be considered feasible sources for production of bio-diesel. As mentioned earlier, the waste fish oil in Iran can be considered a source of renewable fuel. Furthermore, studies reveal that the research programs in waste fish oil bio-diesel is at its infancy phase, which would be speeded up with the support and incentives provided by the Iranian Government [57,58].

In Iran, algae-based bio-diesel production is gaining much importance because of the country's capacity to promote algae cultivation. The Maharlu salt lake, Urmia salt lake, Qom salt lake, Zagros Mountains, Persian Gulf and Caspian Sea are the regions in Iran that contribute to the expansion of new species of algae. The preliminary studies in Iran to promote algae-based bio-diesel have reported affirmative results [59]. Despite their advantages, the major limitations like low biomass concentration, low oil content and economics were predominant from micro algae bio-diesel production. However, micro algae genetic engineering methods can be adopted to enhance the bio-fuel production in Iran [60].

3.14. Ireland

Ireland has set target to substitute 10% bio-fuels to conventional fossil fuels by 2020. To accomplish this target, the arable lands in Ireland would not be sufficient to encourage bio-fuel crops as it shows the way to food-fuel conflict.

Thamsiriroj and Murphy [61] focused on the bio-diesel generation from readily available residues in the country. The renewable and sustainable resources for probable bio-diesel production in Ireland are animal tallow and used cooking oil. In the country, the number of livestock had been estimated to be twice its residents, and a survey had reported that about 9 million livestock were slaughtered annually. Based on the data collected in 2010, the potential collectible used cooking oil in Ireland was around 15.3 thousand t/a. Thus, the tallow and cooking oil residues would be potentially considered to be the unconventional resources in Ireland for production of bio-diesel.

Murphy and Power [62] examined the possibility of promoting second-generation bio-fuel crops in Ireland. The authors have identified silage grass would be a viable green energy resource for bio-fuel generation. It had been noted that over 90% of Irish agricultural land are taken by the silage grass. The authors have estimated around 25% of bio-methane generation is possible from silage, and the production cost of bio-methane was calculated to be €0.034/MJ.

3.15. Italy

An investigation on impacts of green house gas emissions on bio-diesel production from rapeseed, Soybean and sunflower (potential alternative crops to achieve the European bio-diesel targets in Italy) was compiled by Buratti et al. [63]. The estimated emission values for three preferred crops were compared with the European Union renewable energy directive. The assessment was carried out with agricultural data related to Umbrian province and Veneto province of Italy. The analysis revealed that the calculated emission values were higher for sunflower and rape oilseeds, whereas the values were lower for soy oil seeds. Taken as a whole, the study suggested the need to adopt improved processing steps to further reduce the green house gas emissions from bio-fuel crops in Italy.

Cardone et al. [64] estimated the use of *Brassica Carinata* as an alternative crop for the production of bio-diesel in Italy. The study was primarily focused on the agronomic and energetic aspects, fuel production by transesterification and characterization. The results proved *Brassica Carinata* oil crop to be the promising crop for cultivation in the coastal regions of central-southern Italy.

Furthermore, the preliminary assessment on the impacts of bio-diesel production in Italy was carried out by Russi [65]. The author has reported that the investment in bio-diesel is not reliable in Italy. Although there have been gains in planting bio-fuel-based crops in Italy, the depressing impacts were evaluated to be greater than that of gains. The huge environmental threat in case of agricultural phase and the considerable increase in food imports would be of chief concern. Russi stressed the need to go for second-generation bio-fuel production, and also the necessary changes are to be brought out by the policy-makers to promote current bio-diesel significance in Italy.

3.16. Malaysia

The equatorial climate in Malaysia provides a fitting circumstance for the development of bio-energy crops. The country can be the leading bio-diesel contributor in the world via palm oil. The tropical weather in Malaysia paves way for production and supply of huge magnitude of palm oil. The bio-diesel program in Malaysia had been started in 1982 using palm oil as feedstock. After

systematic studies, the country announced its national bio-fuel policy in 2005. The policy has environmental barriers for adoption, because only one feedstock (palm) is considered for bio-fuel production. Even though the economics and higher oil yield/ha of palm oil was valuated to be superior to other oil seed crops utilized in bio-diesel production, the expansion program of palm tree plantation in the country would substantially direct to ecological unsteadiness and replacement of other valuable agricultural crops [66,67].

The prospects of bio-diesel from *Jatropha curcas* in Malaysia was studied by Mofijur et al. [68]. The practicability of *Jatropha curcas* as bio-diesel feedstock in Malaysia is at the infancy stage comparing with palm oil. The country has adequate land to promote the cultivation of *Jatropha curcas* as a bio-diesel resource. In the country, a total land area of 1712 ha has been identified for primary production of *Jatropha curcas.* It is anticipated that in near future *Jatropha curcas* would be a sustainable feedstock for the bio-fuel production along with palm oil in Malaysia. In addition to *Jatropha curcas,* algae would also be utilized for bio-fuel generation [69].

Even though national bio-fuel policy of Malaysia has publicized immediate and long-term benefits, especially on improving the demand of palm oil, the use of inedible oilseed crops like *Jatropha curcas* and *Calophyllum inophyllum* as potential feedstock for bio-diesel production have to be accelerated [70,71].

3.17. Mali

The Malian government is encouraging the cultivation of *Jatropha curcas* to meet the country's energy demands. The country hopes to ultimately power all of the country's villages with renewable energy sources. Apart from *Jatropha curcas,* food crops like cassava could provide a practicable source of bio-fuel production in Mali. The Sikasso province in the southern division of Mali is well-known for Cassava cultivation. It is indispensable to analyze the effects of bio-fuel production on the above and below-ground carbon stocks before commercializing it on large-scale. One such investigation on the impacts of Cassava-based bio-ethanol production on above-ground carbon stocks was outlined by Rasmussen [72]. The land use change from unsown to Cassava resulted in reduction of above-ground carbon stocks. Finally, the authors recommended that future progress should be focused in solving issues concerned with food adequacy and security.

3.18. Mexico

In Mexico, the energy consumption by transportation sector increases year by year due to the fabulous growth in population as well as economical development of the country. To alleviate the environmental concerns on land use by planting bio-energy crops, the preliminary assessment of bio-diesel generation from meat industry residues in Mexico was evaluated by Toscano et al. [73]. The bio-diesel generation from available waste fat in Mexico proved that the produced bio-diesel would be a possible surrogate to diesel to power the passenger vehicles and trucks in the state. Further, to support the Mexican transportation sector, palm oil bio-diesel program would be a promising option. Lozada et al. [74] analyzed the environmental and economic feasibility of palm oil-based bio-diesel using B5 (until 2015) and B10 (from 2016–2031) in the Mexican transportation sector. The study indicated that the execution of palm bio-diesel project in the transportation sector would substitute the diesel fuel consumption. Besides, the cumulative reductions in environmental emissions would be achievable. In addition, the cost-benefit analysis proved to be feasible in implementing palm oil bio-diesel in Mexico.

3.19. Mozambique

In northern Mozambique, an estimation of small-scale *Jatropha* bio-diesel development has been crucially analyzed by Rasmussen et al. [75]. The case-study demonstrated that *Jatropha* cultivation would be successfully carried out in the forest regions of the Northern provinces without distressing agricultural lands. Moreover, the expansion of *Jatropha* would most likely to reduce the above and below-ground carbon stocks. Therefore, the authors have stressed the need to measure the site-specific carbon impacts caused by the land use change allied with the expansion of *Jatropha* cultivation.

3.20. Norway

Norway has the potential to produce bio-diesel from the animal fat and fish residues. The three largest cities, Bergen, Trondheium, and Oslo in Norway has been recognized the country's largest centers to afford animal fat from grease traps. In addition, fish residue that is being dumped at sea would be a feasible source to produce bio-diesel, which would replace the use of petro-diesel as well as mitigate the carbon dioxide emission [76].

3.21. Pakistan

Like India, Pakistan is a developing nation that highly relies on imported crude oil, and the domestic edible oil production in the country is not adequate to meet the present day demands. The development of renewable and sustainable energy sources in Pakistan is at the early phase. About 80 million ha of fallow land in Pakistan could be utilized for bio-fuel crop cultivation. In addition, the marginal lands grant an opportunity to develop engineered ponds for the growth of algae for bio-diesel production. The saline soil in the country provides an occasion to cultivate *Jatropha* plants. The country has set target to blend 10% (B10) bio-diesel with neat diesel by 2025. On the whole, the commitment and constant engagement of the Pakistani government is needed to find the solutions to endorse green energy resources in the country [77–79].

3.22. Peru

In Peru, oil palm and *Jatropha* are the two major feedstocks provide an opening to develop bio-diesel market of the country at the national level. The excellent agro climatic conditions of Peruvian Amazonian jungles offer a basis for plantation of palm and *Jatropha.* Over years, palm oil (edible oil) has been widely used in cooking and food processing applications throughout the world. Recent statistics report that over 10% of world palm oil is being considered for bio-diesel production. On the other hand, *Jatropha*-based bio-diesel has gained importance in several countries like India, Tanzania and Zambia. *Jatropha curcas* is an inedible oilseed crop, so the bio-diesel from *Jatropha* would provide food-security. Conversely reports state that in Peru, oil palm would be a suitable feedstock because of their higher yield and low production cost than *Jatropha.* However, there is need to ensure the intermittent supply of edible palm oil in the country when palm cultivation is commercialized on large-scale in Peru [80].

3.23. Tanzania

The united republic of Tanzania of eastern Africa remains to be the predecessor in *Jatropha* cultivation. The bio-fuel investment in the country is highly controversial issue. The *Jatropha* bio-fuel in Tanzania evolved towards sustainability since early 2005 to an early-stage sector system innovation and production in late 2009 [81]. The substitution of mineral diesel with locally produced

Jatropha oil for provision of rural electrification in Tanzania is pleasing. Grimsby et al. [82] presented the energy flow in rural electrification with *Jatropha* oil in Tanzania. The study was focused on Engaruka Juu village in Arusha region of the country. The suitable climatic circumstances of Engaruka seem to provide better growth conditions of *Jatropha.* Hence, the human energy requirements in Tanzania would be achieved through multifunctional platform connected to the local grid. In addition, the findings recommended the need to use the readily available wastes to support the rural electrification. However, there is a need to provide generous financial assistance to make rural electrification a practical preference in Tanzania.

3.24. Thailand

In Thailand, crude palm oil could be a potential feedstock for bio-diesel production. The oil palm cultivation in Thailand is mostly concentrated in the three southern regions, Karbi, Chumporn and Surat Thani, where more than 70% of palm cultivation area is located [83,84]. Besides palm oil production and utilization in Thailand, the country has competence to export palm oil. Preliminary studies reveal that it would be a viable choice to import oil palm from Thailand to produce bio-diesel in Ireland than production of bio-diesel from Irish native oil seed rape, which was perceived to be a high-energy input crop than imported oil palm [85]. And, the implications on land use change towards palm cultivation in Thailand illustrated that there was a diminution in green house gas emissions than mineral diesel [86]. Furthermore, in order to improve the existing palm bio-diesel system in Thailand, there is a need to analyze the environmental aspects of palm oil production on large-scale capacity in the country [87].

Although palm oil has been considered a major feedstock for bio-diesel production in Thailand, in order to avoid the food-fuel conflict in future, the inedible oilseed crop, *Jatropha curcas* might be considered as one of the other promising crops [88,89]. In sequence with palm and *Jatropha,* Roselle oil, coconut oil, and animal facts could be used as an alternative feedstocks for bio-diesel production in Thailand [90–92].

Overall, to make the bio-diesel production an environmentally attractive process, bio-catalyst transesterification is much preferred over convention process. In this regard, palm, *Jatropha,* papaya, and rambutan would be cost-effectively considered as feedstocks for lipase-catalyzed bio-diesel production in Thailand [93].

3.25. Turkey

The strong agricultural background of turkey contributes a basis for practical bio-fuel generation. In the country, sunflower oilseed crop would be a possible alternative source for bio-diesel production. The crop cultivation could be expanded in the regions of Aegean, Mediterranean and south-eastern Anatolia regions. A short analysis reveals that the cultivation of potential bio-fuel oilseed crops, such as sunflower and oil seed rape as secondary products during cultivation would bestow hopeful results. Thus, the use of bio-diesel as an alternative fuel in compression ignition engine seems to be economical, which tends to trim down the high tax rates paid on fuel imports in Turkey. Further, the Turkish government should clearly define the bio-diesel policy along with possible revisions in legislation to promote the Turkish bio-diesel market globally [94,95].

3.26. United States

In the United States, soybean oil stay behind to be the largest feedstock consumed for bio-diesel production among other feedstock inputs such as canola oil, corn oil, cotton seed oil, palm oil, and animal fats. Recent survey reports that U.S. production of bio-diesel was estimated to be 912 million gallons during Jan–Nov 2012. This scenario is about 54 and 593 million gallons more than the production in Jan–Nov 2011 and 2010 [96]. Conversely the

Table 3
Major/possible bio-fuel feedstocks in each country (*key finding from the study*).

Country	*Potential bio-fuel feedstocks*
Argentina	Soybean Sunflower Crambe abyssinica Jatropha macrocarpa
Australia	Physic nut (*Jatropha curcas*) Pongam (*Milletia Pinnata*) Indian mustard (Brassica juncea) Calophyllum inophyllum
Bangladesh	Pongamia Pinnata Rubber seed
Brazil	Soybean Sugarcane Palm
Canada	Canola Sunflower Soybean
Chile	Residual wood (from Radiata pine and Eucalyptus) Camelina Rapeseed
China	Rapeseed Micro algae
Cuba	*Jatropha curcas* Neem Moringa
Ghana	Palm
Greece	Sunflower Cotton seed Rapeseed Tomato seed Tobacco seed Pumpkin seed
India	*Jatropha curcas*
Iran	Palm Jatropha Castor Algae Fish oil
Ireland	Animal tallow Used cooking oil Silage grass
Italy	Rapeseed Soybean Sunflower
Kenya	Castor
Malaysia	Palm Jatropha Curcas Calophyllum inophyllum
Mali	*Jatropha curcas*
Mexico	Palm Tallow
Mozambique	*Jatropha curcas*
Norway	Animal fat Fish residues
Pakistan	*Jatropha curcas*
Peru	Palm *Jatropha*
South Africa	Canola Sunflower Soybean
Tanzania	*Jatropha*
Thailand	Palm *Jatropha*
Turkey	Sunflower Rapeseed
United states	Soybean
Zimbabwe	*Jatropha curcas*

country's bio-diesel production volume in early 1997 was estimated to be 8 mt [97]. Thus, this increased drift in production capacity in recent days is possible from the 112 bio-diesel plants with an annual production capacity of 2, 130 million gallons/year. Even though U.S. has experienced a rapid expansion in bio-diesel production worldwide, the policy impacts on sustainable bio-fuel development is still under deliberation.

3.27. Zimbabwe

The least developed country, Zimbabwe imports almost all its oil needs. Also, the country has set target to blend 10% bio-fuel by 2017. The availability and suitability of land with hopeful agro-ecological conditions in the country could promote the cultivation of *Jatropha*. The most ideal region for *Jatropha* plantation would be the low-end regions based on the general elevation viewpoint. However, the land tenure issues will have an effect on the allocation of land for *Jatropha* plantation. Hence, the bio-fuel execution in Zimbabwe highly relies on specific-site aptness of bio-fuels for the country as well as to the locality [98,99].

Overall, the country wise available raw material for bio-fuel production is summarized in Table 3.

It is clear from Table 3 that the oilseed crops, such as sunflower, soybeans, *Jatropha*, palm, and rapeseed are the foremost feedstocks used for bio-diesel production world wide. Out of the above mentioned feedstocks, the oilseed palm and *Jatropha* are the key raw materials widely used for bio-diesel production in African and Asian provinces. Additionally, Sunflower, Soybeans, and Rapeseed are the oilseed crops most commonly used for bio-diesel production in American and European provinces. Besides oil seed crops, animal residues are of primary interest for bio-diesel production in the European regions of Ireland and Norway.

4. Conclusion and recommendations

Present day, the exploit of renewable technologies is on the rise in each developing and developed nation, but the renewable energy sources are not 'green' as they appear. Therefore, the implementation of more dominant, viable, and supple alternative renewable energy source to the conventional energy source is a demanding task. Moreover, the current bio-fuel technologies are not proposed up to the stipulated level. So, a proper planning measure, optimization technique and stringent standards are required to enforce such quality systems. Based on the review conducted, three major conclusions are drawn,

- The first major conclusion pictures that the use of bio-fuel in road vehicles have had a far-flung ripple effects on food-based agricultural lands. Besides, present day scenario clearly states that in major countries the land already set aside for renewable energy production is not sufficient.
- The second major conclusion emphasises the need to conduct further studies in second generation bio-fuel crops such as grasses, since the first generation bio-fuel crops have shown more negative impacts than gains.
- The third and last major conclusion suggests a need to conduct further research and development in bio-diesel production technology, and a large-scale impact of bio-fuel policy on agricultural lands have to be critically analyzed. And, an in-depth study on performance and emission characteristics in real-world environment has to be suitably studied.

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